

## The Relationship of Isometric Grip Strength and Anthropometric Parameters

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**Abstract:** Grip strength has been used as a measure of function in various health-related conditions. Grip strength has a specific role in ergonomics especially for hand tool using. It also reduces the risk of potential injuries associated with using of hand tool. Grip strength decreases in repetitive hand activities, and that it will recover after an "adequate" rest period. It will be helpful in determining when return to work after taking sufficient rest period. The aims of this study were not only to determine the relationship between isometric grip strength and recovery but also to evaluate potential factors that influence grip strength. We evaluated dominant hand grip strengths in 20 male and 20 female subject's age range of 20 to 51 years who participated in the study. Factors assessed for potential association with grip strength were; demographics such as age and gender; body constructs such as height and weight; upper extremity such as the linear dimensions of elbow to wrist length, hand length and hand breadth. Descriptive statistics were used to predict optimal handle position. Linear regression analysis was performed in order to identify influencing factors independently associated with grip strength. Pearson product correlation was performed to identify linear relationship among parameters. Through descriptive statistics based on greatest mean grip strength optimal handle position was found position-3 (3.5 cm) for male and position-2 (3.0 cm) for female. Mean grip strength of male was found greater than female. Grip strengths of male and female in dominant hands were found to decrease with aging, and were significantly different between male and female, as expected. Linear regression analysis indicated that weight and hand breadth in male and age and weight in female had a significant effect on grip strength. The other anthropometric parameters had combined influence on the pre-exercise isometric grip strength (dependent variable) for both male and female. Z-test also indicated that there were no significant differences on the rate of recovery at each point in time between male and female.

**Keywords:** Grip strength, Anthropometric Parameter, Recovery, crush grip, pinch grip, support grip.

### I. INTRODUCTION

The ability to grip is one of the most important functions of the hand, and grip strength can be used to reflect overall muscular strength [1]. Grip strength has been used as a measure of function in various health-related conditions. Hand grip strength is an easily obtainable measure of physical health and muscle function. Reliable and valid evaluation of hand strength is very important in determining the effectiveness of various surgical or treatment procedure. Grip strength has been found to be associated with numerous factors such as demographics (age, gender), body construct (height, weight, bone mineral density [BMD], hand size, upper arm circumference, hand dominance), socioeconomic variables (occupation, social status, lifestyle) and physical and psychosocial variables. Recovery is the time required for repair of damage strength to the body. The loss of muscular strength of hand is caused by forceful grip strength. The more forceful grip strength required more recovery time to regenerate the muscular strength. Furthermore, grip strengths significantly differ between ethnicities [2]. This study examines the relationship of several anthropometric variables to isometric grip strength and the handle position of the Digital Analyzer at which greatest strength is achieved. This study also examines the relationship between grip strength and recovery. Findings which demonstrate that greatest strength values are obtained at a specific handle position and that position is significantly different than the other two handle positions.

### II. BACKGROUND OF THE STUDY

Since the late 19th Century, assessment of isometric grip strength has been an interest of numerous fields, involving physical educators, anthropologists, and physician as well as occupational therapists [3]. Many of these have sought overt data, such as loss or gain of grip strength, or have wished to compare different populations. Interest in relationships of various human factors and human performance to grip strength has characterized past research [4]. Although numerous dynamometers have been developed, researchers have turned toward the use of models with adjustable handle settings, allowing for adjustment of the instrument to the size of the human hand or for assessing strength at various spans of grip [5, 6]. The value of earlier studies has been limited by the lack of standardized anthropometric technique, the lack of grip strength assessment protocols which are consistent with current practice, and the use of a wide variety of dynamometers, many of which are not in common use in occupational therapy clinics. Such information is certainly useful to the occupational therapist as part of grip strength evaluation, but also offers an increased understanding of the dynamics of human grasp as it relates to body dimensions and the size of the object grasped. The ability to generate power of an individual depends on the force that he or she can apply to produce work. The more work can be performed, if more power is generated. Grip strength can be used to reflect overall muscular power as a measure of work capacity of an individual [36]. This study is mainly done to focus the influence of various ergonomics factors or anthropometric dimensions such as age, weight, height and upper extremity on grip strength and its recovery.

We followed the following process to conduct our research:

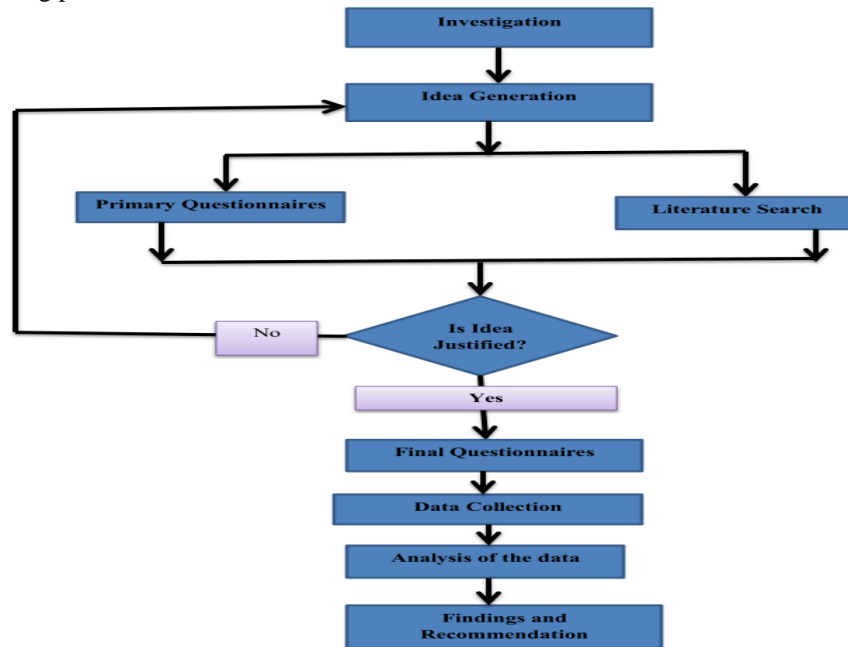


Figure 1: Action plan of the research work.

### III. ANALYSIS

#### 3.1 Introduction

This part contains a description of the methods used to conduct this study. Areas discussed include, description of the subjects, equipment, measurement procedures, data collection methods and data analysis. The aim of this part is to communicate the results of the information gained through data collection. This chapter presents the key findings and analysis of the study.

#### 3.2 Description of Subjects

Forty healthy subjects (20 males and 20 females) were recruited to be volunteers for this study. Subjects selected were between the ages of 20 and 51 years old. Dominance of hand was determined by statement of the subject. Personal data were collected from each subject include age and hand dominance. Exclusion criteria were participating in a regular sport or physical activity, having any fractural injury in any part of the hand, having any operation in arm, wrist or hand, and suffering from pain in upper limb at present.

#### 3.3 Equipment

1. The standard, adjustable-handle dynamometer (Digital Analyzer grip/pinch)
2. Grip transducer.
3. Standard comfortable chair.
4. Weight measuring instrument.
5. Measuring scale.

#### 3.4 Measurement and Data Collection Procedures

Data collection procedures were divided into two parts

##### 3.4.1 Grip strength measurement

Each subject was informed detail about our study and questioned about exclusionary criteria to participate in the study. For predicting optimal handle position of dynamometer we took grip strength data for three positions for each subject in three several days. Grip strength was assessed using a Digital Grip Analyzer. This consists of adjustable two flat padded bars mounted parallel to each other maximum 3.5 cm apart. When these are squeezed together the maximum force is indicated on a digital display which registers from 0 to 1999 Newton (that is, from light touch to heavy pressure). Isometric grip strength data of each subject was measured by a Digital Grip Analyzer. The dynamometer (digital analyzer) was designed to record accurately the pressure exerted on the bars irrespective of the point of grip along their length. For maximum isometric grip strength measurement, the subjects were seated with the hand resting comfortably in a standard height chair. A person's grip strength usually results in having the strongest grip strength when their forearm is neutral and the elbow at 90° before their body. The dynamometer was placed with a marked point on one bar against the web of skin between the thumb and index finger. The digital display was then set to zero, thus discounting any resting pressure exerted by the people due to involuntary flexion of the fingers. The observer stood immediately in front of the subject. The grip transducer was then placed in the subject's right hand, with the observer lightly cupping the handle at the base of the instrument in his right hand and the observer lightly supporting digital analyzer front display them with his left hand. The

observer then insured that the grip transducer was being held in such a position that the subject's wrist was nearly deviated between neutral and 15 degrees.



Figure 2: Monitor

To set the display to zero by pressing the zero button on the digital display unit for a minimum of 2 seconds. The Digital Display Unit cannot indicate negative values and so it is necessary to press the zero buttons even if the display already reads zero. Choosing the units we would like the force to be displayed as, on the Digital Display Unit, by pressing the appropriate button on the front panel. We preferred unit of force is in Newton. Each subject was told to squeeze the handles of this instrument as hard as possible and then release. The handles will not move as it squeeze, but the instrument will record the grip strength. The handle width can be adjusted so as to accommodate different hand sizes. A scale is attached to the handle so that a note of the handle width may be taken to ensure that any re-tests are comparable. For predicting the optimal positioning of the handle both male and female subjects, grip strength data was taken for each three position in three several days. From each male subject three grip strength data was taken for the position of handle width at 2.5, 3.0 and 3.5 cm. From each female subject was also taken three grip strength data for the position of width at 2.5, 3.0 and 3.5 cm. Grip strength data of three handle positions were analyzed by descriptive statistics. According to greatest mean value the handles of the digital analyzer were set at Position-2 (3.0 cm apart) for female and at Position-3 (3.5 cm apart) for male.



Figure 3: Squeezing by hand.

The person was told to squeeze the handle as hard as possible and then release after 3 sec. To get the maximum applied force, we activated the hold facility by ensuring that the hold button is pressed in. (in = on, out = off). Then we read the reading and wrote the data in collection sheet. Adequate recovery time (20 to 30 s) was given between the subsequent measurements to negate the fatigue factor [36]. With an inter task interval (20-30 sec) for each trial this procedure was repeated three times. At the beginning of isometric grip strength measure, we recorded one data which was mentioned as pre-exercise strength of that person. After that we took three grip strength data with duration (3 sec) and inter task interval (20-30 sec) for each trial followed by the recommendations of Caldwell et al. [35]. In the same way, three trials for after 1 min, 5 min, 10 min, and 20 min rest period this procedure were repeated.

### 3.4.2 Anthropometric measurement:

The linear dimensions of elbow to wrist length, hand length and hand breadth were selected because of their relationship to the height of the subject. All anthropometric dimensions data for each subject was taken with the help of a measurement scale. All anthropometric dimensions were measured once and these measurements were used in data analysis. Anthropometric measurements were recorded in the data collection sheet.

### 3.5 Data Analysis

Statistical analyses were analyzed using statistical packages for the social sciences (SPSS) for windows version 17.0 and statistical significance was accepted for P values of  $< 0.05$ .

Z-test (proportion test), linear regression and Pearson correlation analysis were used to find whether differences exist between males and females subjects. Pearson product-moment correlation coefficient was used in the analysis of the associations of anthropometric variables. Due to the composite nature of many of the anthropometric measurements and the number of dimensions, linear regression analysis was used to be more appropriate in clarifying the nature of the relationships. Data were summarized into mean and standard deviation values using descriptive statistics.

Table 1: Anthropometric comparison of subjects across gender groups

| Descriptive Statistics |             |    |         |         |        |                |
|------------------------|-------------|----|---------|---------|--------|----------------|
| Gender                 |             | N  | Minimum | Maximum | Mean   | Std. Deviation |
| Male                   | Age (years) | 20 | 21      | 51      | 33.85  | 10.256         |
|                        | Height (cm) |    | 160     | 180     | 170.05 | 5.790          |
|                        | Weight (kg) |    | 47      | 82      | 65.15  | 8.229          |
| Female                 | Age (years) | 20 | 20      | 45      | 28.10  | 7.469          |
|                        | Height (cm) |    | 147     | 165     | 156.30 | 5.079          |
|                        | Weight (kg) |    | 46      | 64      | 55.65  | 4.464          |

Table 1 shows the mean and standard deviation of age, height and weight of 20 male and 20 female subjects.

### 3.5.1 Predicting optimal handle position

The pre-requirement of our study is to predict optimal handle position of the digital analyzer. It was analyzed with the descriptive statistics.

Optimal handle position is defined as the handle position of the digital analyzer at which highest mean of isometric grip strength is achieved.

Table 2: Predicting optimal handle position

| Descriptive Statistics |                     |    |                        |                  |               |                |
|------------------------|---------------------|----|------------------------|------------------|---------------|----------------|
| Gender                 |                     | N  | Grip strength (Newton) |                  |               |                |
|                        |                     |    | Minimum (Newton)       | Maximum (Newton) | Mean (Newton) | Std. Deviation |
| Male                   | Position-1 (2.5cm)  | 20 | 135                    | 501              | 305.20        | 74.525         |
|                        | Position-2 (3.0 cm) |    | 144                    | 523              | 322.30        | 78.729         |
|                        | Position-3 (3.5cm)  |    | 139                    | 538              | 334.70        | 85.273         |
| Female                 | Position-1 (2.5 cm) | 20 | 114                    | 195              | 160.35        | 25.707         |
|                        | Position-2 (3.0 cm) |    | 118                    | 206              | 164.70        | 26.754         |
|                        | Position-3 (3.5 cm) |    | 109                    | 210              | 154.85        | 27.446         |

There is a need to study the relationship of grip strength to handle position of the digital analyzer. If grip strength varies significantly between handle positions, there is a need to determine the adjustment of the handle position for each individual. Three handle positions were selected which were 2.5 cm, 3.0 cm, and 3.5 cm. From descriptive analysis, for the handle position of 2.5 cm, 3.0 cm and 3.5 cm of male, mean were found 305.20 N, 322.30 N, and 334.70 N respectively. In the similar way, mean were found for female 160.35 N, 164.70 N, and 154.85 N respectively which are shown in table 2 and graphically in figure 4 & 5. Because greatest mean were found at handle position-3 (3.5 cm apart) for male, followed by handle positions 1 & 2, and at handle position-2 (3.0cm apart) for female followed by handle position-1 & 3. So the optimal handle positions of the digital analyzer for male and female are 3.5 cm and 3.0 cm respectively.

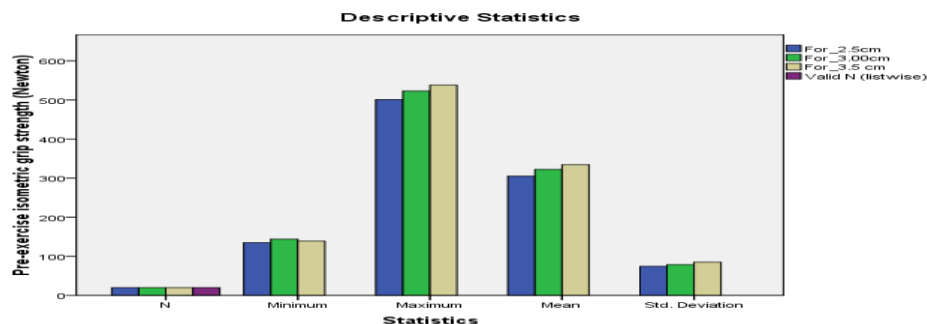


Figure 4: Optimal handle position for male.

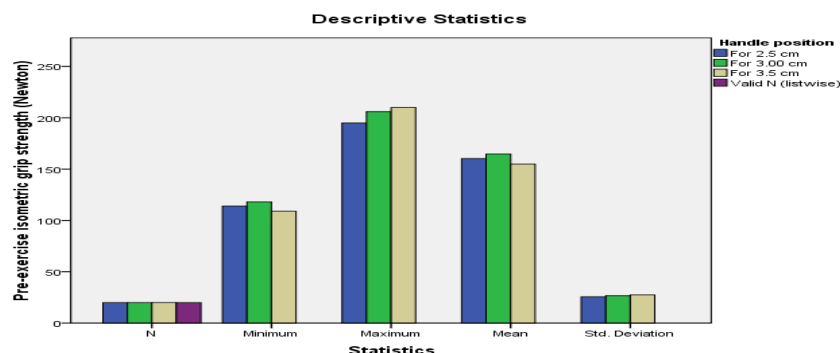


Figure 5: Optimal handle position for female.

Table 3: Comparison mean of pre-exercise isometric grip strength between male and female

| Gender |  | N  | Minimum | Maximum | Mean   | Std. Deviation |
|--------|--|----|---------|---------|--------|----------------|
| Male   | Pre-exercise isometric strength (Newton) | 20 | 139     | 538     | 334.70 | 85.273         |
| Female | Pre-exercise isometric strength (Newton) | 20 | 118     | 206     | 164.70 | 26.754         |

The table 3 shows the comparison of Mean and S.D of pre-exercise isometric grip strength between male and female for the optimal handle position. The grip strength mean of male is 334.70 N with S.D of  $\pm 85.273$  and the grip strength mean of

female is 164.70 N with S.D of  $\pm 26.754$ . This result shows that grip strength of male is higher than female. This result is graphically shown in figure 6.

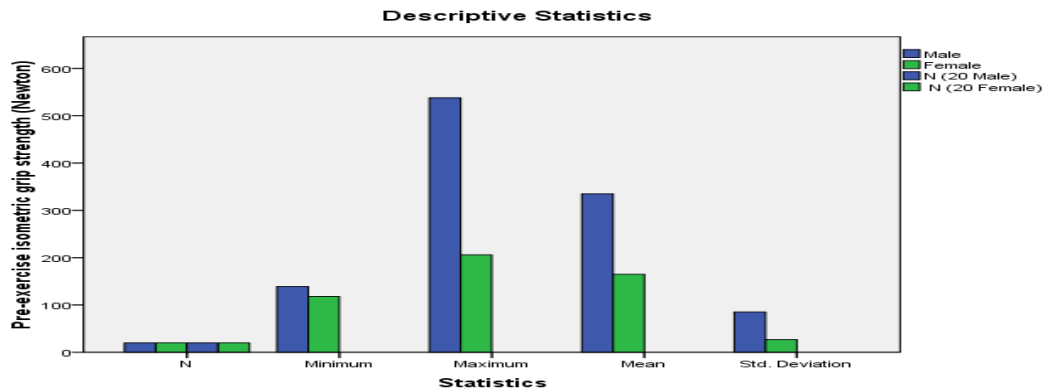


Figure 6: Comparison of pre-exercise isometric grip strength between male and female.

### 3.5.2 Determination of relationship between isometric grip strength and recovery:

The first objective was to determine the relationship between isometric grip strength and recovery. It was analyzed by Z-test (proportion test) to identify any significance among groups.

Table 4: Effect of recovery rate on time to recovery.

| Group          | Male (n <sub>1</sub> ) | Female (n <sub>2</sub> ) | Percentage of male(%p <sub>1</sub> ) | Percentage of female(%p <sub>2</sub> ) | Z value | P-value  |
|----------------|------------------------|--------------------------|--------------------------------------|--|---------|----------|
| A (<= 5 min.)  | 20                     | 20                       | 20                                   | 15                                     | 0.416   | 0.338705 |
| B (<= 10 min.) | 16                     | 17                       | 37.5                                 | 23.5                                   | 0.875   | 0.1907   |
| C (<= 20 min.) | 10                     | 13                       | 50                                   | 53.8                                   | 0.181   | 0.4282   |
| D (> 20 min.)  | 5                      | 6                        | 50                                   | 46.2                                   | 0.126   | 0.44986  |

Z proportion test were performed after grouping the subjects in terms of the point in time when each subject returned to his or her initial isometric grip strength level. Those subjects who recovered within 5 min were placed in Group A, those who recovered within 10 min were placed in Group B, those who recovered within 20 min were placed in Group C, and those who required more than 20 min to recover were placed in Group D. There were no significant differences among the groups in terms of the rate of recovery at each point in time. In Group A there were 7 subjects (4 males and 3 females) recover within five minutes whose Z value was 0.416. In Group B there were 10 subjects (6 males and 4 females) recover within ten minutes whose Z value was 0.875. In the same way in Group C there were 12 subjects (5 males and 7 females) recover within 20 minutes whose Z value was 0.181. But in Group D there were 11 subjects (5 males and 6 females) did not recover fully within 20 minutes whose Z value was 0.126. The table 4 shows that, the P value of each Groups is greater than 0.05. So based on P value it is concluded that, all groups are insignificant in terms of the rate of recovery at each point in time. This is depicted in table 4 and graphically in Figure 8.

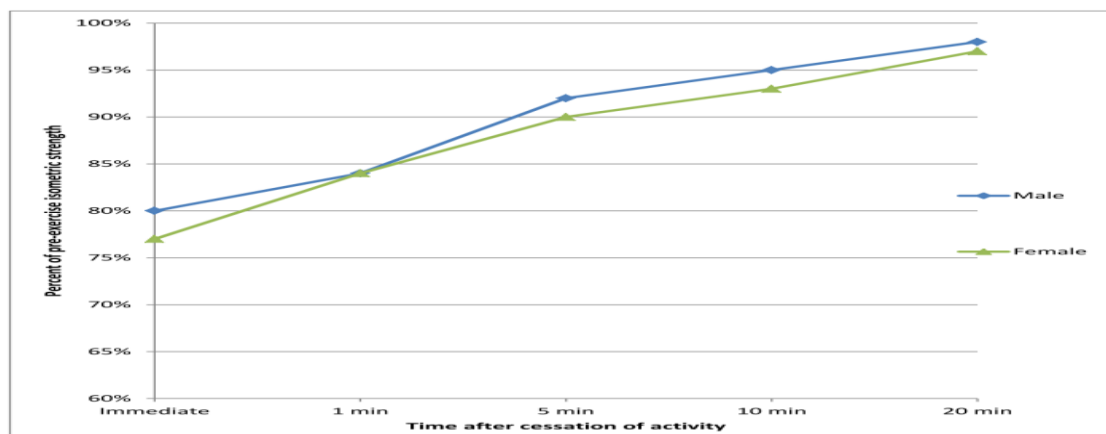


Figure 7: Comparison of gender groups in terms of post exercise isometric strength recovery as a percent of pre-exercise isometric strength [36].

The figure 7 gives a graphical representation of comparison of gender groups in terms of post exercise isometric strength recovery as a percent of pre-exercise isometric strength. Time after cessation of activity are plotted in X axis and percent of pre-exercise isometric strength data are plotted in Y axis. Average percentage of post exercise isometric grip strength data of male and female are plotted at different time span. This graph shows, recovery rate increases

with the rise of recovery time. From this graph it is also evident that recovery rate of male is greater than the recovery rate of female.

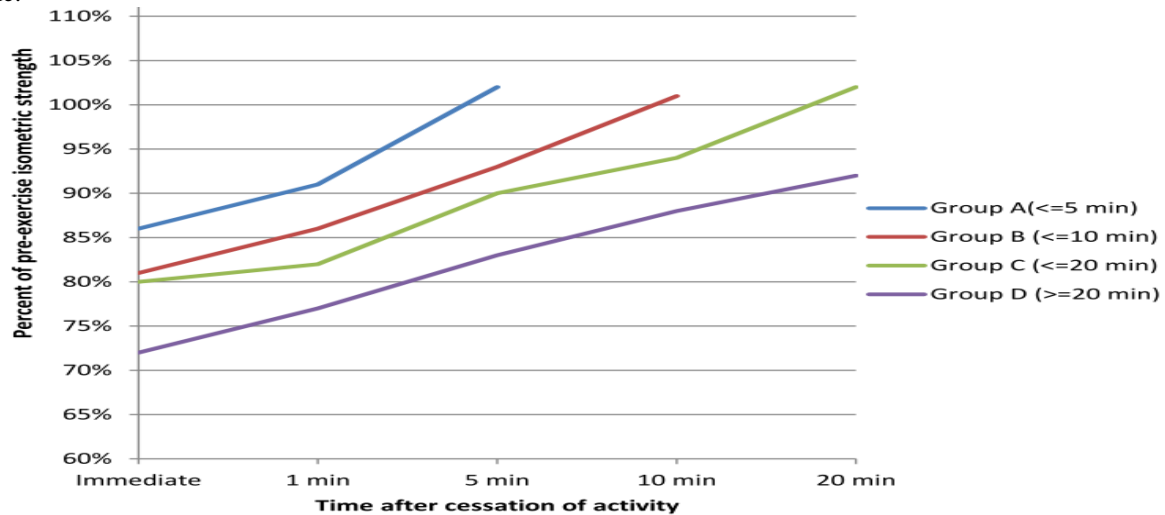


Figure 8: Relationship between post exercise isometric strength and recovery across groups based on time to recover to pre exercise strength [36].

In figure 8, time after cessation of activity are plotted in X axis and percent of pre-exercise isometric grip strength data are plotted in Y axis. Average post exercise isometric grip strength data for each group is plotted against cessation of activity. It is seen that the recovery rate of Group A is greatest among other groups followed by Group B & Group C. However group D did not recover fully within twenty minutes.

### 3.5.3 Determination of the relationship among anthropometric variables and isometric grip strength in the three selected handle position

The second objective was to determine the relationship among anthropometric variables and isometric grip strength in the three selected handle position. It was analyzed by Pearson product-moment correlation coefficients.

Table 5: Relationship between anthropometry variable and isometric grip strength in handle position for male.

| Male   |                     |                          |                           |                           |
|--|---------------------|--------------------------|---------------------------|---------------------------|
| Anthropometric variables                                     |                     | Handle position          |                           |                           |
|  |                     | Position -1<br>For 2.5cm | Position -2<br>For 3.00cm | Position -3<br>For 3.5 cm |
| Age (years)  | Pearson Correlation | -.640**                  | -.637**                   | -.692**                   |
|  | Sig. (2-tailed)     | .002                     | .003                      | .001                      |
|  | N                   | 20                       | 20                        | 20                        |
| Height (cm)  | Pearson Correlation | .761**                   | .783**                    | .803**                    |
|  | Sig. (2-tailed)     | .000                     | .000                      | .000                      |
|  | N                   | 20                       | 20                        | 20                        |
| Weight (kg)  | Pearson Correlation | .648**                   | .640**                    | .611**                    |
|  | Sig. (2-tailed)     | .002                     | .002                      | .004                      |
|  | N                   | 20                       | 20                        | 20                        |
| Elbow to wrist length (cm)                                   | Pearson Correlation | .602**                   | .631**                    | .664**                    |
|  | Sig. (2-tailed)     | .005                     | .003                      | .001                      |
|  | N                   | 20                       | 20                        | 20                        |
| Hand length (cm)   | Pearson Correlation | .739**                   | .755**                    | .729**                    |
|  | Sig. (2-tailed)     | .000                     | .000                      | .000                      |
|  | N                   | 20                       | 20                        | 20                        |
| Hand breadth (cm)  | Pearson Correlation | .266                     | .255                      | .235                      |
|  | Sig. (2-tailed)     | .257                     | .278                      | .318                      |
|  | N                   | 20                       | 20                        | 20                        |
| *. Correlation is significant at the 0.05 level (2-tailed).  |                     |                          |                           |                           |
| **. Correlation is significant at the 0.01 level (2-tailed). |                     |                          |                           |                           |

From the table 5 it is seen that the values of the correlation coefficients were highest for the variables age, height, weight, elbow to wrist length and hand length. Except hand breadth all the anthropometric variables are significantly correlated with the handle position-3. Hand breadth has poor coefficient value in three handle position. Weight demonstrated significant correlations with isometric grip strength in handle position-1 and position-2. Hand breadth was not significantly related to isometric grip strength in any handle position because p-value is greater than 0.05. Age was negatively correlated

with isometric grip strength in three positions, it means with the increase of age grip strength will decrease. The correlation of age, height and elbow to wrist length become stronger with the increment of handle size.

### 3.5.3.1 Percentile ranking

Some software packages, including (up to the version 2013) use the following method, to estimate the value,  $v_P$  of the  $P$ -th percentile of an ascending ordered dataset containing  $N$  elements with values  $v_1 \leq v_2 \leq \dots \leq v_N$ .

The rank is calculated by the following formula:

$$n = \frac{P}{100} (N - 1) + 1$$

Where,

$n$  = Rank,  $P$  = Percentile,  $N$  = Population

And then split into its integer component  $k$  and decimal component  $d$ , such that  $n = k + d$ . Then  $v_P$  is calculated as:

$$v_P = \begin{cases} v_1, & \text{for } k = 0 \\ v_N, & \text{for } k = N \\ v_k + d(v_{k+1} - v_k), & \text{for } 0 < k < N \end{cases}$$

Where  $v_p$  is the value of percentile [35]

#### Calculation of 95<sup>th</sup> percentile for male:

The ascending order of pre-exercise isometric grip strength is: 139, 224, 268, 282, 283, 288, 289, 296, 311, 336, 341, 346, 360, 369, 370, 392, 392, 427, 443, 538

$$n = \frac{P}{100} (N - 1) + 1$$

Rank,

$$= \frac{95}{100}(20-1) + 1 = 19.05 = 19 + 0.05$$

Here,  $k = 19$  and  $d = 0.05$

The value of 95<sup>th</sup> percentile,  $v_p = v_k + d(v_{k+1} - v_k) = 443 + 0.05 * (538 - 443) = 443 + 4.75 = 447.75$

#### Calculation of 5<sup>th</sup> percentile for male:

$$n = \frac{P}{100} (N - 1) + 1$$

Rank,

$$= \frac{5}{100}(20-1) + 1 = 1.95 = 1 + 0.95$$

Here,  $k = 1$  and  $d = 0.95$

The value of 5<sup>th</sup> percentile,  $v_p = v_k + d(v_{k+1} - v_k) = 139 + 0.95 * (224 - 139) = 139 + 80.75 = 219.75$

In the similar way the value of 75<sup>th</sup>, 50<sup>th</sup>, 25<sup>th</sup> percentile of pre-exercise isometric grip strength for male were calculated, which has shown in table 6.

Table 6 Percentile ranking of elbow to wrist length in terms of isometric grip strength for male

| Male | N  | Percentile                  |   |
|------|----|-----------------------------|---|
|      | 20 | Elbow to wrist length (cm)  | Pre-exercise isometric grip strength value (Newton) |
|      |    | 95 <sup>th</sup> percentile | 28 447.75   |
|      |    | 75 <sup>th</sup> percentile | 26 375.5  |
|      |    | 50 <sup>th</sup> percentile | 25 338.5  |
|      |    | 25 <sup>th</sup> percentile | 24.75 286.75  |
|      |    | 5 <sup>th</sup> percentile  | 23.95 219.75  |

Table 6 shows the 95<sup>th</sup>, 75<sup>th</sup>, 50<sup>th</sup>, 25<sup>th</sup> and 5<sup>th</sup> percentile of elbow to wrist length and pre-exercise isometric grip strength for male. Percentile was analyzed by Microsoft Excel. 95<sup>th</sup> percentile of elbow to wrist length with respect to pre-exercise isometric grip strength value is calculated 28 cm & 447.75 N, which means elbow to wrist length and pre-exercise isometric grip strength value of 95% population is equal or below 28 cm & 447.75 N respectively. In the similar way, 5<sup>th</sup> percentile of elbow to wrist length with respect to pre-exercise isometric grip strength value is calculated 23.95 cm & 219.75 N, which means elbow to wrist length and pre-exercise isometric grip strength value of 5% population is equal or below 23.95 cm & 219.75 N respectively.

Table 7: Relationship between anthropometry variables and isometric grip strength in handle position for female.

Female

Anthropometric variables

Handle position

For 2.5cm

For 3.00cm

For 3.5 cm

|                            |                     |         |         |         |
|----------------------------|---------------------|---------|---------|---------|
| Age(years)                 | Pearson Correlation | -.656** | -.669** | -.686** |
|                            | Sig. (2-tailed)     | .002    | .001    | .001    |
|                            | N                   | 20      | 20      | 20      |
| Height (cm)                | Pearson Correlation | .137    | .239    | .242    |
|                            | Sig. (2-tailed)     | .563    | .310    | .305    |
|                            | N                   | 20      | 20      | 20      |
| Weight (kg)                | Pearson Correlation | .479*   | .551*   | .525*   |
|                            | Sig. (2-tailed)     | .033    | .012    | .017    |
|                            | N                   | 20      | 20      | 20      |
| Elbow to wrist length (cm) | Pearson Correlation | .610**  | .697**  | .704**  |
|                            | Sig. (2-tailed)     | .004    | .001    | .001    |
|                            | N                   | 20      | 20      | 20      |
| Hand length(cm)            | Pearson Correlation | .062    | .023    | .092    |
|                            | Sig. (2-tailed)     | .795    | .922    | .701    |
|                            | N                   | 20      | 20      | 20      |
| Hand breadth (cm)          | Pearson Correlation | .551*   | .584**  | .609**  |
|                            | Sig. (2-tailed)     | .012    | .007    | .004    |
|                            | N                   | 20      | 20      | 20      |

\*. Correlation is significant at the 0.05 level (2-tailed).

\*\*Correlation is significant at the 0.01 level (2-tailed).

From the table 7 it is seen that the values of the correlation coefficients were highest for the variables age, weight and elbow to wrist length and hand breadth. Except height and hand length all the variables are significantly correlated with three handle positions. Height and hand length have poor coefficient value in three handle position. Age was negatively correlated with isometric grip strength in three positions, it means with the increase of age grip strength will decrease.

#### Calculation of 95<sup>th</sup> percentile for female:

The ascending order of pre-exercise isometric grip strength is: 118, 120, 128, 138, 148, 152, 155, 155, 158, 159, 163, 168, 172, 182, 187, 188, 196, 200, 201, 206

$$n = \frac{P}{100} (N - 1) + 1$$

Rank,

$$= \frac{95}{100} (20-1) + 1 = 19.05 = 19 + 0.05$$

Here, k = 19 and d = 0.05

The value of 95<sup>th</sup> percentile  $v_p = v_k + d (v_{k+1} - v_k) = 201 + 0.05 * (206 - 201) = 201 + 0.25 = 201.25$

#### Calculation of 5<sup>th</sup> percentile for female:

$$n = \frac{P}{100} (N - 1) + 1$$

Rank,

$$= \frac{5}{100} (20-1) + 1 = 1.95 = 1 + 0.95$$

Here, k = 1 and d = 0.95

The value of 5<sup>th</sup> percentile  $v_p = v_k + d (v_{k+1} - v_k) = 118 + 0.95 * (120 - 118) = 118 + 1.9 = 119.9$

In the similar way the value of 75<sup>th</sup>, 50<sup>th</sup>, 25<sup>th</sup> percentile of pre-exercise isometric grip strength for female were calculated, which has shown in table 8.

Table 8 Percentile ranking of elbow to wrist length in terms of isometric grip strength for female

| Female | N  | Percentile                  |   |
|--------|----|-----------------------------|---|
|        | 20 | Elbow to wrist length (cm)  | Pre-exercise isometric grip strength value (Newton) |
|        |    | 95 <sup>th</sup> percentile | 25 201.25   |
|        |    | 75 <sup>th</sup> percentile | 24 187.25   |
|        |    | 50 <sup>th</sup> percentile | 23 161  |
|        |    | 25 <sup>th</sup> percentile | 23 151  |
|        |    | 5 <sup>th</sup> percentile  | 22 119.9  |

Table 8 shows the 95<sup>th</sup>, 75<sup>th</sup>, 50<sup>th</sup>, 25<sup>th</sup> and 5<sup>th</sup> percentile of elbow to wrist length measurement for female. Percentile was analyzed by Microsoft Excel. 95<sup>th</sup> percentile of elbow to wrist length with respect to pre-exercise isometric grip strength value is calculated 25 cm & 201.25 N, which means elbow to wrist length and pre-exercise isometric grip strength value of 95% population is equal or below 25 cm & 201.25 N respectively. In the similar way, 5<sup>th</sup> percentile of elbow to wrist length

with respect to pre-exercise isometric grip strength value is calculated 22 cm& 119.9 N, which means elbow to wrist length and pre-exercise isometric grip strength value of 5% population is equal or below 22 cm& 119.9 N respectively.

### 3.5.4 Determination the relationship between isometric grip strength and influencing anthropometric factors

The third objective was to determine the relationship between isometric grip strength and influencing anthropometric factors. It was analyzed not only by Pearson product-moment correlation coefficients but also linear regression analysis was used to be more appropriate in clarifying the nature of the relationships.

Table 9: Correlations of anthropometric factors and isometric grip strength for male.

| Correlation  |                     |                                 |
|--|---------------------|---------------------------------|
| Male   |                     |                                 |
| Anthropometric variables                                     |                     | Pre-exercise isometric strength |
| Age (years)  | Pearson Correlation | -.692**                         |
|  | Sig. (2-tailed)     | .001                            |
|  | N                   | 20                              |
| Height (cm)  | Pearson Correlation | .803**                          |
|  | Sig. (2-tailed)     | .000                            |
|  | N                   | 20                              |
| Weight (kg)  | Pearson Correlation | .611**                          |
|  | Sig. (2-tailed)     | .004                            |
|  | N                   | 20                              |
| Elbow to wrist length (cm)                                   | Pearson Correlation | .664**                          |
|  | Sig. (2-tailed)     | .001                            |
|  | N                   | 20                              |
| Hand length(cm)  | Pearson Correlation | .729**                          |
|  | Sig. (2-tailed)     | .000                            |
|  | N                   | 20                              |
| Hand breadth(cm)   | Pearson Correlation | .235                            |
|  | Sig. (2-tailed)     | .318                            |
|  | N                   | 20                              |
| *. Correlation is significant at the 0.05 level (2-tailed).  |                     |                                 |
| **. Correlation is significant at the 0.01 level (2-tailed). |                     |                                 |

The table 9 shows the relationships between anthropometric variables and isometric grip strength by Pearson product-moment correlation coefficients for male. The correlation coefficients are high for age, height, weight, elbow to wrist length and hand length. The correlation coefficient between age and isometric grip strength is -0.692 ( $p = .001$ ), which is negatively correlated and it means with the increase of age grip strength will decrease. It also shows the correlation coefficient value of height .803 ( $p = 0.0001$ ), weight .611 ( $p = .004$ ), elbow to wrist length .664 ( $p = .001$ ), Hand length .729 ( $p = 0.0001$ ). Hand breadth has poor correlation to isometric grip strength, because its coefficient value is .235 ( $p = .318$ ).

Table10: Correlations of anthropometric factors and isometric grip strength for female.

| Correlations   |                     |                                 |
|--|---------------------|---------------------------------|
| Female   |                     |                                 |
| Anthronometric variables                                     |                     | Pre-exercise isometric strength |
| Age (years)  | Pearson Correlation | -.669**                         |
|  | Sig. (2-tailed)     | .001                            |
|  | N                   | 20                              |
| Height (cm)  | Pearson Correlation | .239                            |
|  | Sig. (2-tailed)     | .310                            |
|  | N                   | 20                              |
| Weight (kg)  | Pearson Correlation | .551*                           |
|  | Sig. (2-tailed)     | .012                            |
|  | N                   | 20                              |
| Elbow to wrist length (cm)                                   | Pearson Correlation | .697**                          |
|  | Sig. (2-tailed)     | .001                            |
|  | N                   | 20                              |
| Hand length (cm)   | Pearson Correlation | .023                            |
|  | Sig. (2-tailed)     | .922                            |
|  | N                   | 20                              |
| Hand breadth(cm)   | Pearson Correlation | .584**                          |
|  | Sig. (2-tailed)     | .007                            |
|  | N                   | 20                              |
| **. Correlation is significant at the 0.01 level (2-tailed). |                     |                                 |
| *. Correlation is significant at the 0.05 level (2-tailed).  |                     |                                 |

The table 10 shows the relationships between anthropometric variables and isometric grip strength by Pearson product-moment correlation coefficients for female. The correlation coefficients are high for age, weight, elbow to wrist length and hand breadth. The correlation coefficient between age and isometric grip strength is -0.669 ( $p = 0.001$ ), which is negatively correlated and it means with the increase of age grip strength will decrease. It is also shows the correlation coefficient value of weight .551 ( $p = 0.012$ ), elbow to wrist length .697 ( $p = 0.001$ ), Hand breadth .584 ( $p = 0.007$ ). Height and hand length have poor significant correlation to isometric grip strength, because the coefficient value of height is .239 ( $p = .310$ ) and hand length is .023 ( $p = .922$ ).

Table 11: Model summary of dependency of pre- exercise isometric grip strength on the anthropometric variables for male

| Male  |          |                   |                            |               |
|---|----------|-------------------|----------------------------|---------------|
| Model Summary <sup>b</sup>  |          |                   |                            |               |
| R   | R Square | Adjusted R Square | Std. Error of the Estimate | Durbin-Watson |
| .915 <sup>a</sup>   | .838     | .763              | 41.556                     | 3.015         |
| a. Predictors: (Constant), Hand breadth (cm), Weight (kg), Elbow to wrist length (cm), Age (years), Hand length (cm), Height (cm) |          |                   |                            |               |
| b. Dependent Variable: Pre-exercise isometric strength (Newton)   |          |                   |                            |               |

Linear regression model was used to measure the influencing factors for pre- exercise isometric grip strength. Table 11 shows the degree of dependency of pre- exercise isometric grip strength on the independent variables such as age(years), height (cm), weight (kg), elbow to wrist length (cm), hand length (cm), hand breadth (cm).

Multiple correlation R value is 0.915 which means the degree of linear relationship among the dependent variable and other independent variables are strong.

In the study of degree of dependency of dependent variable on explanatory variables,  $R^2 = 0.838$  means that 83.8% variation of pre- exercise isometric grip strength is explained by explanatory variables.

Here  $R^2$  value is adjusted by 76.3% taken into account degree of freedom in order to overcome the short coming of  $R^2$  value. Durbin-Watson test is used to measure auto correlation. Here Durbin-Watson value is 3.015 implies that data set are free from auto correlation.

Table 12: Result of Analysis of variance (ANOVA) for pre- exercise isometric grip strength and the anthropometric variables for male.

| Male   |                |    |             |        |                   |
|--|----------------|----|-------------|--------|-------------------|
| ANOVA <sup>b</sup>   |                |    |             |        |                   |
|  | Sum of Squares | df | Mean Square | F      | Sig.              |
| Regression   | 115708.103     | 6  | 19284.684   | 11.167 | .000 <sup>a</sup> |
| Residual   | 22450.097      | 13 | 1726.931    |        |                   |
| a. Predictors: (Constant), Hand breadth (cm), Weight (kg), Elbow to wrist length (cm), Age (years), Hand length (cm), Height (cm). |                |    |             |        |                   |
| b. Dependent Variable: Pre-exercise isometric grip strength (Newton).  |                |    |             |        |                   |

Analysis of variance (ANOVA) is used to measure the overall significant influence of the independent variables on the dependent variable pre- exercise isometric grip strength. From table 12 it is concluded that over all significance test through F-test implies that the model is significant since F significant ( $F_{6,13} = 11.167$ ,  $p = 0.0001$ ) which means all the independent variables have combined influence on the dependent variable pre- exercise isometric grip strength.

Table 13: Impact (positive or negative) of the anthropometric variables on pre- exercise isometric grip strength for male

| Male                       |              |            |        |      |  |
|----------------------------|--------------|------------|--------|------|--|
| Variables                  | Coefficients | Std. Error | t      | Sig  |  |
| (Constant)                 | -1234.840    | 493.386    | -2.503 | .026 |  |
| Age (years)                | -1.666       | 1.211      | -1.376 | .192 |  |
| Height (cm)                | 3.615        | 5.503      | .657   | .523 |  |
| Weight (kg)                | 2.811        | 1.468      | 1.914  | .078 |  |
| Elbow to wrist length (cm) | 16.672       | 17.714     | .941   | .364 |  |
| Hand length (cm)           | 7.906        | 14.839     | .533   | .603 |  |
| Hand breadth(cm)           | 29.153       | 14.633     | 1.992  | .068 |  |

The estimated value for the independent variables measured the impact (positive or negative) of the variables on dependent variables. Table 13 shows the estimated value for the parameter weight is 2.811 means that if one unit of weight is increased, the average of grip strength is increased 2.811 times, when all other variables are remain constant. The value of t is 1.914 which is significant at the 10% level of significance ( $p < 0.1$ ). The estimated value for the parameter age is -1.666 means that if one unit of age is increased, the average of grip strength is decreased 1.666 times; when all other variables are remain constant. The value of t is -1.376 which is not significant ( $p > 0.1$ ).

So, it is concluded that the parameter weight and hand breadth has a significant effect on isometric grip strength (as  $p < 0.1$  for the both) and the rest variable has no significant effect on isometric grip strength (as  $p > 0.1$ ).

Table 14: Model summary of pre- exercise isometric grip strength on the anthropometric variables for female

| Female  |          |                   |                            |               |
|---|----------|-------------------|----------------------------|---------------|
| Model Summary <sup>b</sup>  |          |                   |                            |               |
| R   | R Square | Adjusted R Square | Std. Error of the Estimate | Durbin-Watson |
| .842 <sup>a</sup>   | .709     | .574              | 17.452                     | 1.745         |
| a. Predictors: (Constant), Hand breadth (cm), Height (cm), Weight (kg), Hand length (cm), Age (years), Elbow to wrist length (cm) |          |                   |                            |               |
| b. Dependent Variable: Pre-exercise isometric strength (Newton)   |          |                   |                            |               |

Table 14 shows the degree of dependency of pre- exercise isometric grip strength on the independent variables such as age(years), height (cm), weight (kg), elbow to wrist length (cm), hand length (cm), hand breadth (cm).

Multiple correlation R value is 0.842 which means the degree of linear relationship among the dependent variable and other independent variables are strong.

In the study of degree of dependency of dependent variable on explanatory variables,  $R^2$  value 0.709 means that 70.9% variation of pre- exercise isometric grip strength is explained by explanatory variables.

Here  $R^2$  value is adjusted by 57.4% taken into account degree of freedom in order to overcome the short coming of  $R^2$  value. Durbin-Watson test is used to measure auto correlation. Here Durbin-Watson value is 1.745 implies that data set are free from auto correlation.

Table 15 Result of Analysis of variance (ANOVA) for pre- exercise isometric grip strength and the anthropometric variables for female.

| Female  |                |    |             |       |                   |
|---|----------------|----|-------------|-------|-------------------|
| ANOVA <sup>b</sup>  |                |    |             |       |                   |
| Model   | Sum of Squares | df | Mean Square | F     | Sig.              |
| Regression  | 9640.733       | 6  | 1606.789    | 5.276 | .006 <sup>a</sup> |
| Residual  | 3959.467       | 13 | 304.574     |       |                   |
| a. Predictors: (Constant), Hand breadth (cm), Height (cm), Weight (kg), Hand length (cm), Age (years), Elbow to wrist length (cm) |                |    |             |       |                   |
| b. Dependent Variable: Pre-exercise isometric grip strength (Newton)  |                |    |             |       |                   |

Analysis of variance ANOVA is used to measure the overall significant influence of the independent variables on the dependent variable pre- exercise isometric grip strength. From table 15 it is concluded that over all significance test through F-test implies that the model is significant since F significant ( $F_{6,13} = 5.276$ ,  $p = 0.006$ ) which means all the independent variables have combined influence on the dependent variable pre- exercise isometric grip strength.

Table 16: Impact (positive or negative) of the anthropometric variables on pre-exercise isometric grip strength for female

| Female                     |              |            |        |      |  |
|----------------------------|--------------|------------|--------|------|--|
| Variables                  | Coefficients | Std. Error | t      | Sig. |  |
| (Constant)                 | 28.492       | 270.470    | .105   | .918 |  |
| Age (years)                | -1.565       | .872       | -1.795 | .096 |  |
| Height (cm)                | -62.977      | 98.665     | -.638  | .534 |  |
| Weight (kg)                | 2.519        | 1.071      | 2.350  | .035 |  |
| Elbow to wrist length (cm) | 5.692        | 9.243      | .616   | .549 |  |
| Hand length (cm)           | -1.580       | 7.652      | -.206  | .840 |  |
| Hand breadth (cm)          | 4.786        | 8.245      | .580   | .572 |  |

The estimated value for the independent variables independent variables measured the impact (positive or negative) of the variables on dependent variables. Table 16 shows the estimated value for the parameter weight is 2.519 means if one unit of weight is increased; the average of grip strength is increased 2.519 times, when all other variables are remaining constant. The value of  $t = 2.350$  which is significant at the 10% level of significance ( $p < 0.1$ ).

The estimated value for the parameter age is -1.565 means if one unit of age is increased; the average of grip strength is decreased 1.565 times, when all other variables are remaining constant. The value of  $t = -1.795$  which is significant at the 10% level of significance ( $p < 0.1$ ).

The estimated value for the parameter hand breadth is 4.786 means that if one unit of hand breadth is increased, the average of grip strength is increased 4.786 times; when all other variables are remain constant. The value of  $t$  is -0.580 which is not significant ( $p > 0.1$ ). So, it is concluded that the parameter age and weight has a significant effect on isometric grip strength (as  $p < 0.1$  for the both) and the rest variable has poor significant effect on isometric grip strength.

#### IV. CONCLUSION

Specific adjustment of the handle for male and female are necessary. In Digital Analyzer, greatest isometric grip strength of female is obtained in handle position two and for male in handle position three. Assessment of the maximum isometric grip strength of female should be done with the Digital Analyzer in handle position two and for male in handle position three.

The results of this study suggest that for male two anthropometric variables weight and hand breadth has an adequate influence on isometric grip strength. The rest variables have little effect on isometric grip strength.

The results also suggest for female two anthropometric variables age and weight has an adequate influence on isometric grip strength. The rest variables have little effect on isometric grip strength.

Significant gender differences were found for initial isometric grip strength and post-exercise isometric grip strength. However, there were no significant differences found between males and females in terms of the rate of recovery at each point in time.

The information that is gathered during this study may lead to a consistent method of measuring the grip strength and increase the value of measurements that are taken. It may also increase the understanding of how grip strength is related to the anthropometric variables. However, this research paper proposes some recommendations for further studies.

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